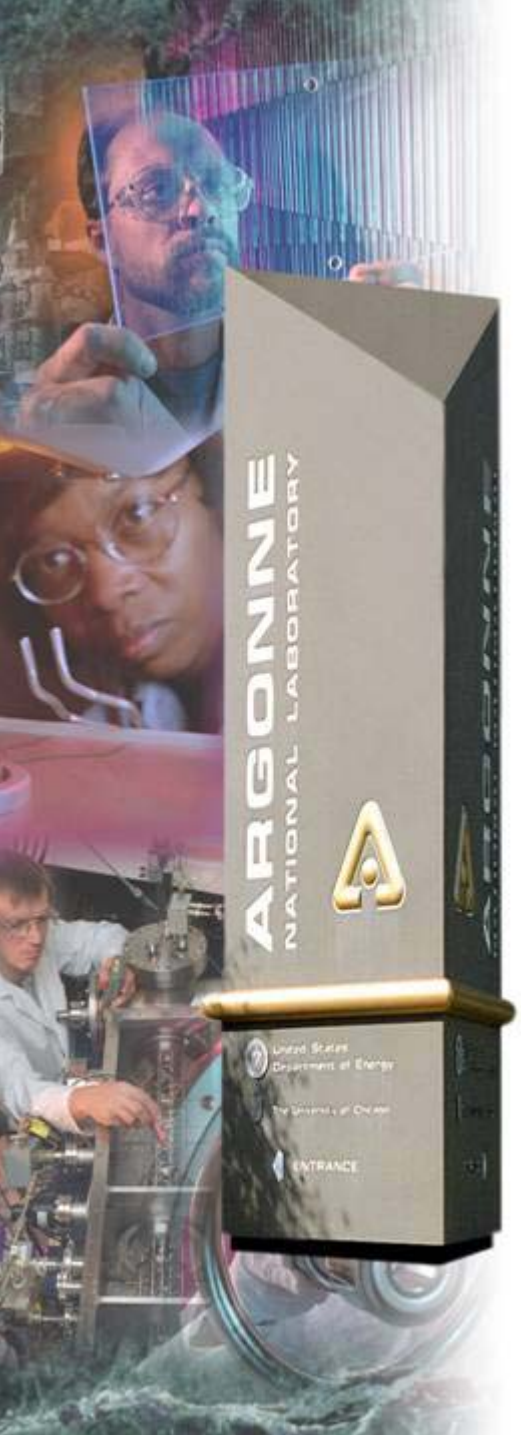

RF Coupler and Tuner Design for the Rare Isotope Accelerator Superconducting Cavities

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Introduction

- **RF power couplers and control systems are employed to operate the low-beta superconducting cavities of the RIA accelerator.**

- **Design decisions on these systems will impact the cost of RIA and the operating expense.**

Outline of Systems

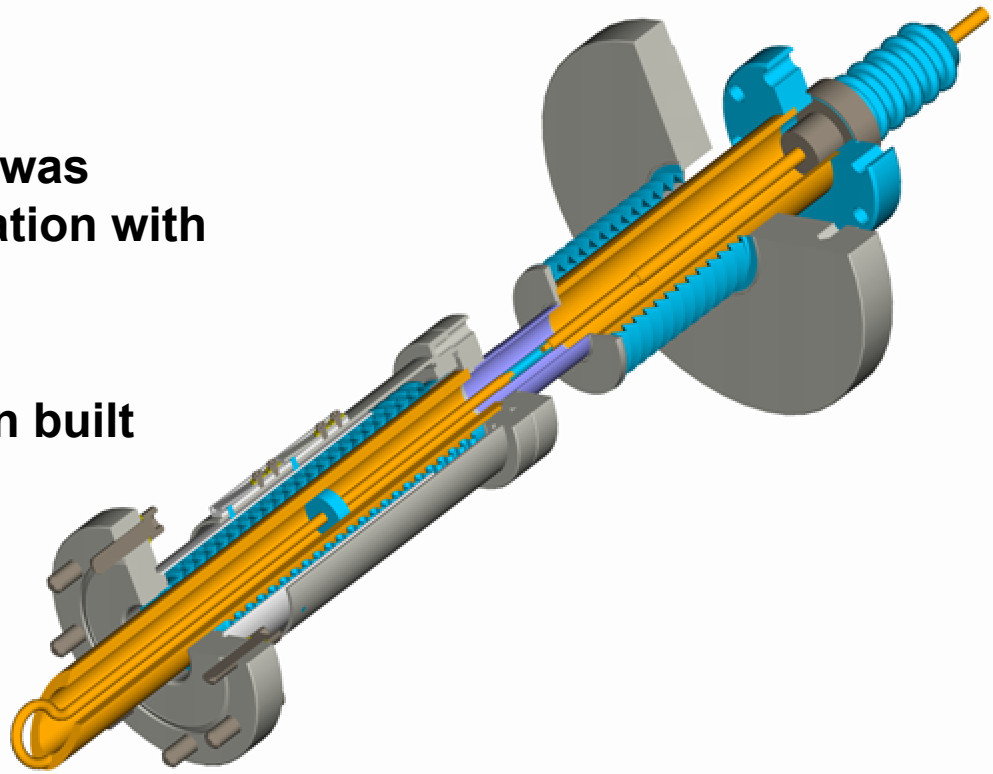
- **RF Power Coupler**
  - integral to be able to couple to the beam loaded Q or over-couple for phase stabilization
- **Slow Tuner**
  - Frequency shifts due to a change in helium pressure may range 10's of Hz per mbar.
- **Phase Stabilization**
  - Beam loading for the low and medium beta RIA cavities will be on the order of 500 to 1500 watts resulting in beam-loaded bandwidths of 50 to 250 Hz.
  - Microphonic-induced frequency noise in most cavities is beyond the beam-loaded bandwidth.
  - Presently there are three methods available for phase stabilization
    1. Over-coupling
    2. Electro-mechanical tuners
    3. Reactive fast tuner (ATLAS)
  - System to dampen mechanical vibration modes in quarter-wave cavities.

RF Power Coupler

- **Need an RF Power coupler design for 20kW CW operation**
  - Frequency range from 57 to 350 MHz
  - Separate vacuum for cavity/vacuum insulation
  - Variable position
  - Clean interior parts

- **A concept for an RF coupler was developed at ANL in collaboration with Porcellato (INFN Legnaro)**

- **A prototype coupler has been built**



ANL Prototype Coupler

- **Features:**
  - Separate cavity/insulating vacuum spaces
  - Clean interior
  - Variable position via an external stepping motor
  - 3 inch stroke
  - Center conductor operates at 80k
  - Presently tested at 7 kW pulsed operation
  - Successfully used to phase stabilize the 350 MHz two-cell spoke cavity

Slow Tuners

- **Several successful methods have been employed at many facilities to compensate for slow frequency drifts due to changes in the helium system pressure:**

  - They all use a mechanical force to deform the cavity
    - *stepping motor and compression screws*
    - *ATLAS uses a pneumatic system with bellows*
    - *under development is pre-loaded magnetostrictive devices*

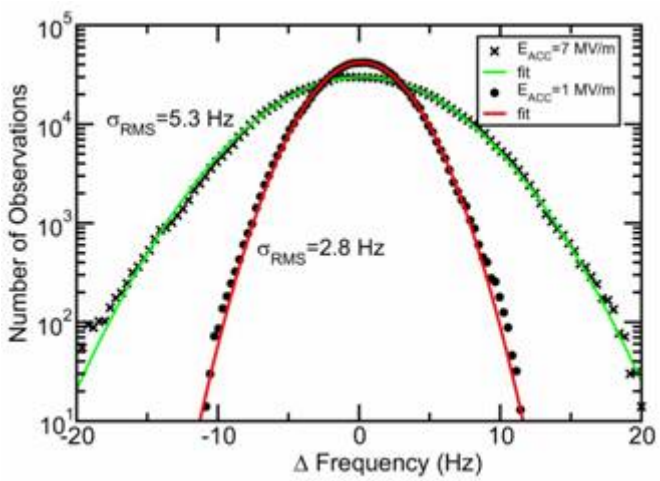
Phase stabilization

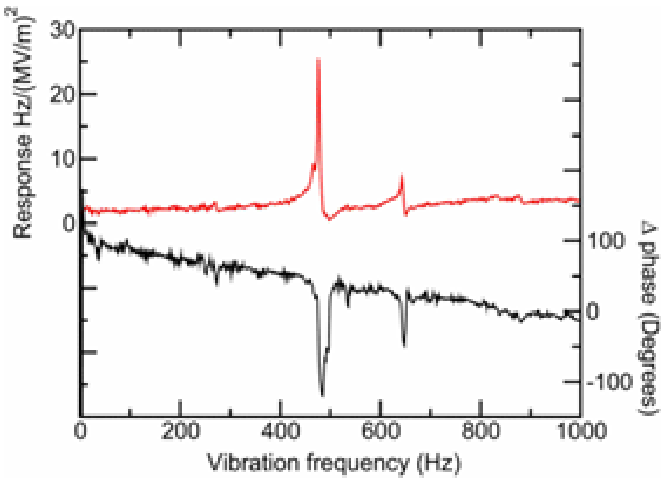
- **There are three methods that currently exist to achieve phase stabilization for low-beta superconducting cavities**

  - Electro-Mechanical methods are under development
    - *Piezo-electric devices*
    - *Magnetostrictive mechanical tuners*
  - *Passive damper (to reduce mechanical motion in quarter-wave cavities)*
  - Over-coupling
  - Reactive fast tuner (ATLAS)

Electro-mechanical Fast Tuner Development

- **Phase stabilization using piezo-electric and magneto-strictive devices currently under development.**
- **At ANL there is a collaboration with Delayan (TJNAF), Rusnak (LLNL) and Simrock (DESY), to phase stabilize the 350 MHz two-cell spoke cavity using the piezo-electric tuner.**
- **Energen (Joshi) will, as part of an SBIR provide ANL with a magneto-strictive tuner to test on a 350 MHz cavity.**

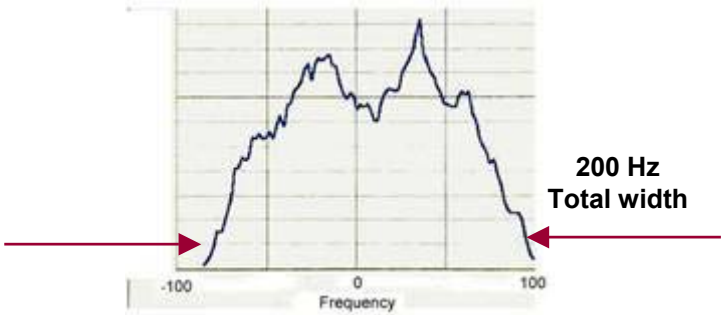


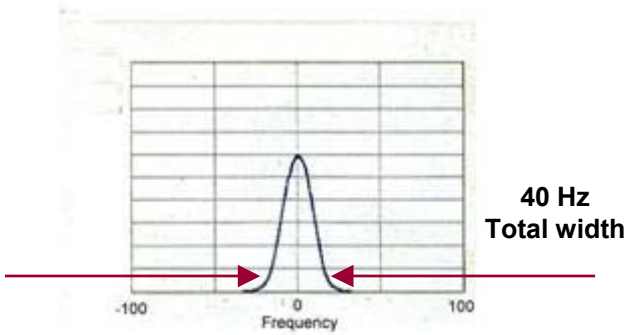


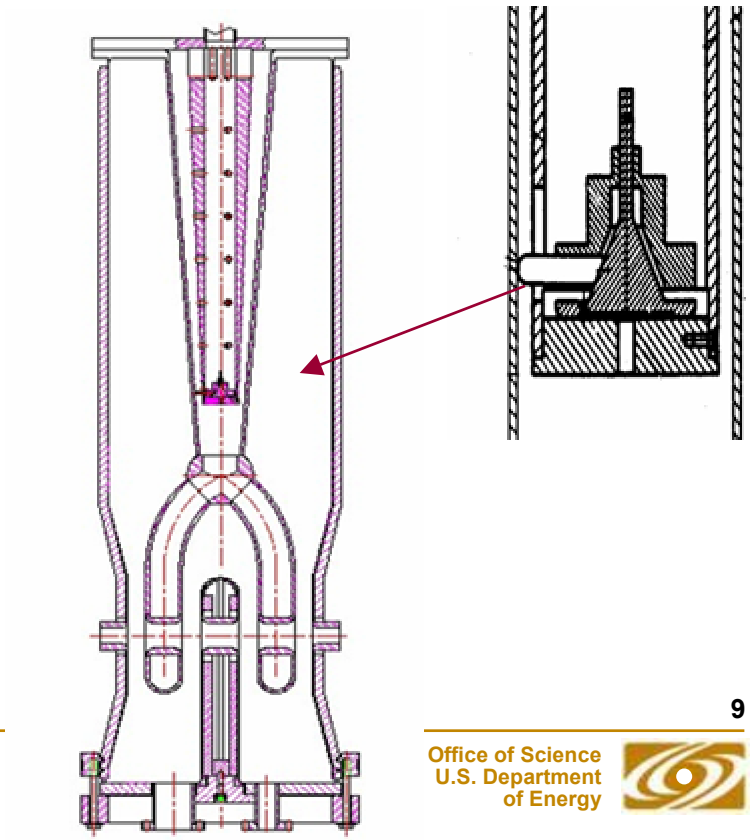
- Will not excite the acoustic modes.
- These devices do not dissipate any of the RF power from the cavity.

Passive Dampers

- A passive device to dampen the mechanical motion of the quarter-wave cavities was developed by Facco (INFN Legnaro)
- This technology is transferable to similar RIA cavities.
- Three dampers of a modified design have been installed at ATLAS.







Phase stabilization by Over-coupling

- increase the bandwidth so that it is larger than the microphonic-induced frequency noise
- provide enough RF power to achieve the desired accelerating field level

- **In cavities where the microphonic noise is large and beam loading is low, the power requirements are also large.**

Phase stabilization by over-coupling

Freq (MHz)	Beta	Emax	Over-coupling Tuning window 50 Hz	100 Hz	200 Hz	BmPWR	Window for Qbeam 50 Hz
57.5	0.02	16	368	735	1471	431	58.56
57.5	0.03	16	744	1487	2974	530	28.96
57.5	0.06	20	1538	3075	6151	557	14.00
115	0.15	20	2168	4337	8674	794	9.93
172.5	0.26	20	5120	10240	20480	1052	4.21
345	0.38	20	1615	3229	6459	1150	13.33
805	0.47	27.5	6964	13927	27855	2161	3.09
805	0.61	27.5	10670	21340	42681	3530	2.02
805	0.81	27.5	16636	33272	66544	5800	1.29
345	0.50	27.5	11366	22732	45463	3175	1.89

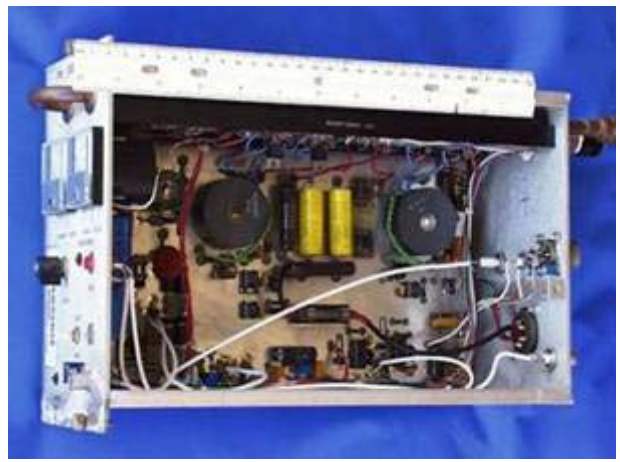
ATLAS Reactive Fast Tuner

- 80K unit based on PIN diode switching technology
- Used to stabilize cavities from 48 to 150 MHz
- The present fast tuner design has successfully switched 35kVAR. To have an equivalent control capability using an over- coupled system it would require a 9 kW RF source.

Freq (MHz)	Beta	Emax	Over-coupling Tuning window 50 Hz	100 Hz	200 Hz	BmPWR	Bm/Win 50 Hz	Fast Tuner ReactivePwr 200Hz	LN2 Dissap.
57.5	0.02	16	368	735	1471	431	58.56	5883	58.827
57.5	0.03	16	744	1487	2974	530	28.96	11897	118.97
57.5	0.06	20	1538	3075	6151	557	14.00	24602	246.02
115	0.15	20	2168	4337	8674	794	9.93	34696	346.96
172.5	0.26	20	5120	10240	20480	1052	4.21		

Component / Cost

Mechanical Unit	**$2.7k**
Electronic Units	
Pulser	$2.2k
Power supplies	$0.630k
RF control section	$1.25k
Assembly Cost	$0.90k
Total	**$7.68k**
LN2 Operating Cost	**$0.19 / cavity hr.**

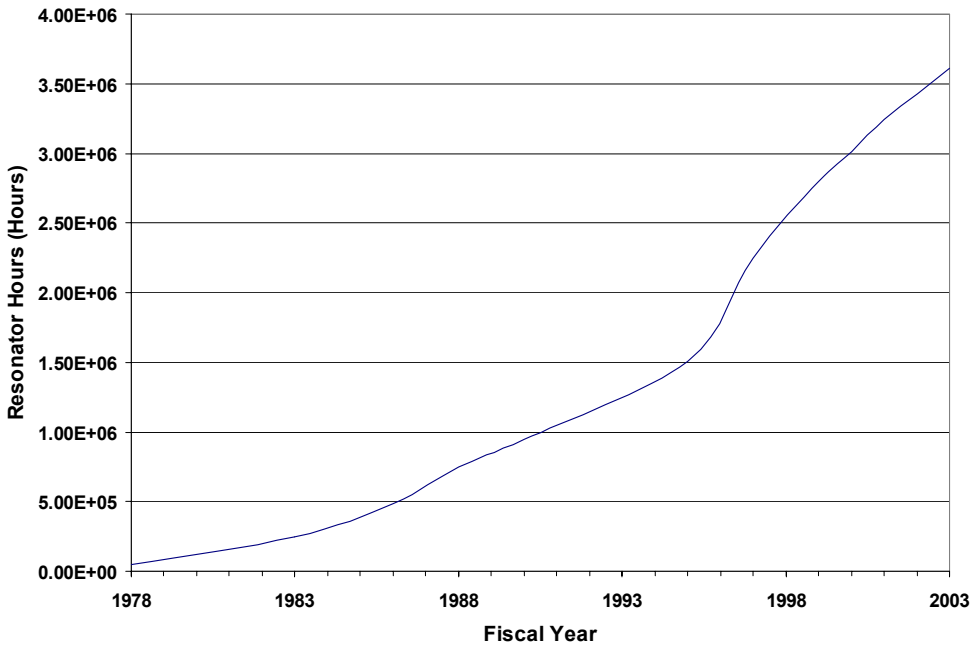


The majority of the RF power is dissipated into LN2 in the fast tuner.

Less than the AC plug power for an RF power amplifier

Fast Tuner Performance

- **ATLAS has over 3.6 million integrated beam-available cavity hours of experience.**



- The fast tuner has been in its current form since about1997.
- Complete operating statistics show from 1997 to the present there has been 1.36 million integrated beam-available cavity hours.
- Since 1997 there has been a total of 84 hours lost time to a failure of the fast tuner system.

Summary

- **Realistic tests on final form RIA cavities are necessary to get real data on microphonics and to make cost effective system design choices.**
- **Build and test the upgraded RF coupler probe**
- **Present slow tuning technology is transferable to RIA.**
- **For phase stabilizing cavities**
  - Over-coupling
  - Continue development on electro-mechanical fast tuners
  - PIN diode reactive fast tuner is a proven system for the RIA low-beta cavities